Recent Operation of the Weapons Neutron Research Facility Sets a New Proton-Beam-Current Record

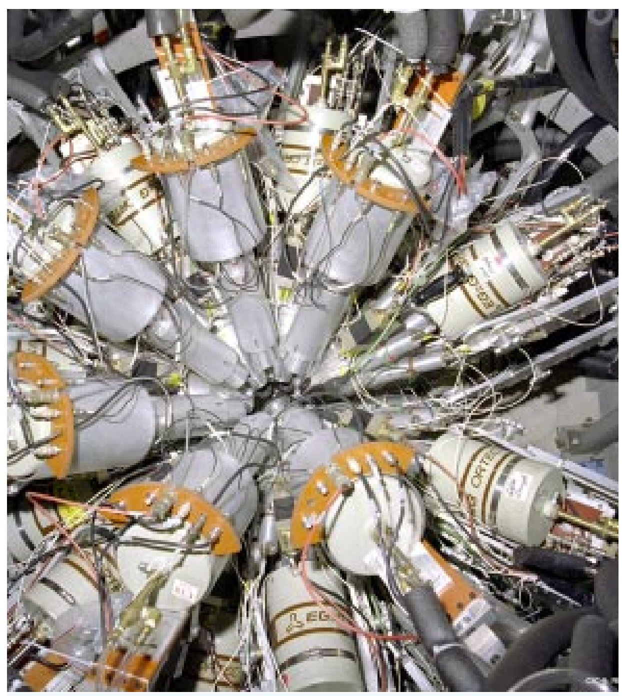
The Weapons Neutron Research Facility (WNR) facility consists of six instrumented high-energy neutron flight paths that view an unmoderated neutron-production target. These six flight paths are operated simultaneously and serve the nuclear science community for basic and applied civilian and weapons-related research. The WNR has been operating continuously for the past four months (beginning in August) at the highest proton current ever achieved for this facility.

At WNR neutrons are produced by spallation reactions following bombardment of a tungsten neutron-production target with the LANSCE 800-MeV proton beam. In typical experiments, the neutron energy is determined by time-of-flight (TOF) techniques. To take advantage of the TOF technique, the proton beam must be pulsed with a time structure tailored to the particular experimental requirements. Because the pulse-to-pulse separation is constrained by TOF requirements, the important figure of merit is the number of protons per pulse. We typically operate with a pulse separation of 1.8 µs.

A recent breakthrough in tuning the LANSCE linac beam through the low-energy beam transport system of the accelerator has resulted in an approximately 50% increase in the number of protons per pulse. This breakthrough coupled with the increase in the number of pulses per second has given the WNR a record amount of proton beam current. In fact, the proton beam current could be increased further but is now limited by restrictions on the power capacity of the target. We are currently operating at approximately 6-µA beam current, which is over twice that of last year's maximum beam.

WNR hosts scientists from universities, industry, national laboratories, and other research facilities from around the world. These researchers use the WNR beams to study a wide variety of basic, applied, and weapons-related topics. Below we list the experiments that have been performed during this past run cycle. Please note that each flight path has a name that depicts the source of the flight path and its direction with respect to the proton beam. For example, 4FP60R is a flight path (FP) that starts at Target 4 (4FP) at WNR and is 60° to the right (60R) of the incoming proton beam.

GEANIE experiments on 4FP60R. A team of scientists from Lawrence Livermore National Laboratory led by Dr. John Becker and a team from Los Alamos National Laboratory led by Dr. Ron Nelson are using the GErmanium Array for Neutron-Induced Excitations, known as GEANIE (Fig. 1), to measure the ^{239}Pu(n,2n) cross section for science-based stockpile stewardship (SBSS) applications. The data are needed to better understand the radiochemical data obtained from past Nevada Test Site experiments. In addition to this measurement, several supporting measurements, including studies of the ^{238,235}U and ^{nat}Fe (n,**x**γ) reactions, are being conducted by this team in support of the SBSS program.



▲ Fig. 1. GEANIE is a large, high-resolution gamma-ray detector that consists of 26 germanium (Ge) detectors surrounded by escape-suppression bismuth germanate (BGO) shields. The array consists of both low-energy gamma-ray planar detectors and high-energy gamma-ray coaxial detectors.

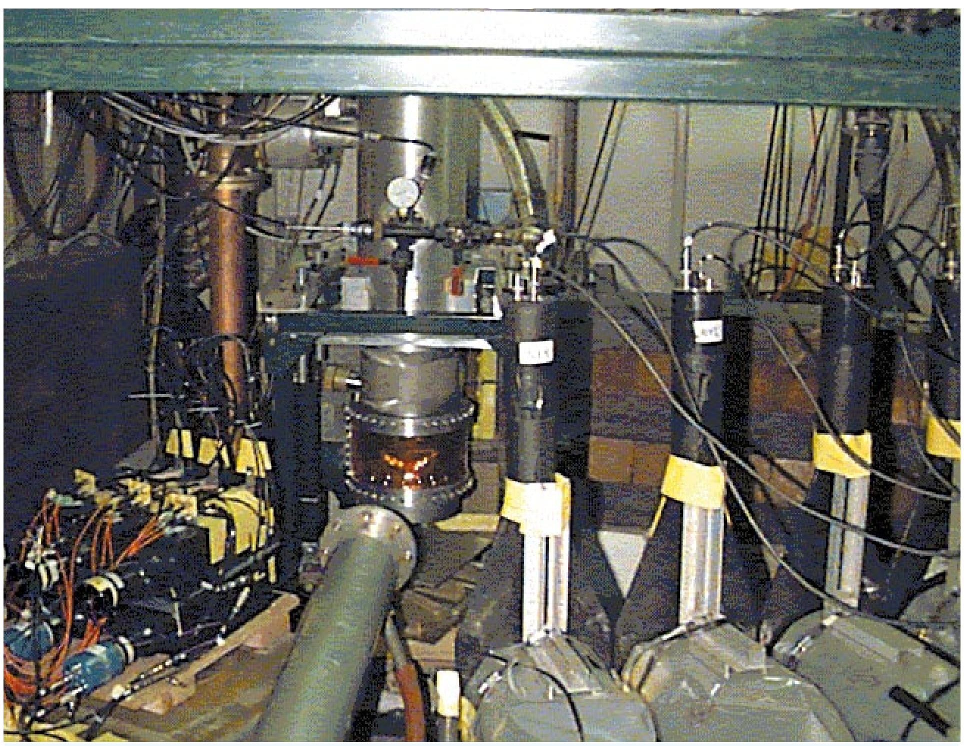
FIGARO experiments on 4FP30R. Dr. Robert Haight and Dr. Matthew Devlin (LANSCE-3) are working with Dr. Luca Zanini (LANSCE-3), a post-doctoral researcher from Italy, and Dr. Ani Aprahamian from Notre Dame to commission the FIGARO (Fast-neutron Induced GAmma-Ray Observer) array. This experimental capability is being developed to complement the experimental capabilities of GEANIE and to relieve some of the time demands on GEANIE. The array will ultimately have four Ge detectors in close geometry along with associated neutron and electron detectors. The experimental program currently under way is focused on studying level densities. Level densities are important input data for codes that predict nuclear reaction rates. Preliminary measurements are being made on the $^{59}Co(n,x\gamma)$ reaction.

Neutron-Proton Bremsstrahlung reaction study on 4FP15R. A group of scientists led by Dr. June Matthews from Massachusetts Institute of Technology (MIT) are completing measurements on the neutron-proton Bremsstrahlung (NPB) reaction (Fig. 2). The data, which will be the topic of MIT student Yashar Safkan's Ph.D. thesis, are the first differential measurement of this fundamental process. As a follow-on experiment using essentially the same apparatus, Dr. William Franklin (MIT) and the MIT group will measure the elastic neutron-deuteron scattering cross section to look for the effects of three-body forces.

$^{3}He(n,2p)$ reaction experiment on 4FP15L. A group of scientists led by Dr. Eugene Pasyuk of Arizona State University in collaboration with Dr. John Ullmann and Dr. Chris Morris of Los Alamos National Laboratory and Dr. June Matthews and students from MIT have been studying the $^{3}He(n,2p)$ reaction to identify the possible contribution of delta isobar excitations in the nuclear ground-state wave function.

Spallation production yield experiment on 4FP15L. An experiment headed by Dr. Janet Sisterson of the Northeast Proton Therapy Center with assistance from Dr. John Ullmann is currently measuring the energy-integrated neutron-spallation cross sections for elements such as natural Ni, Fe, Ti, Si, Al, and Au to obtain cross sections needed to understand cosmic-ray nuclide production in meteorites, lunar samples, and the Earth.

Neutron bombardment experiments on 4FP30L. Several user groups from industry are studying the effects of neutron bombardment on the reliability of semiconductor devices. Neutrons have been shown to cause single-event upsets (SEU) in semiconductor memories. SEUs occur when the charge deposited by a silicon recoil causes the memory location to change its state. Tests can be done at WNR with the same neutron spectrum as produced by cosmic rays in the atmosphere but with an acceleration factor of over $3x10^{5}$ (Fig. 3). The users for this run cycle include scientists from Intel Corporation, Altera Corporation, Saab Corporation, and Texas A&M Prairie View.

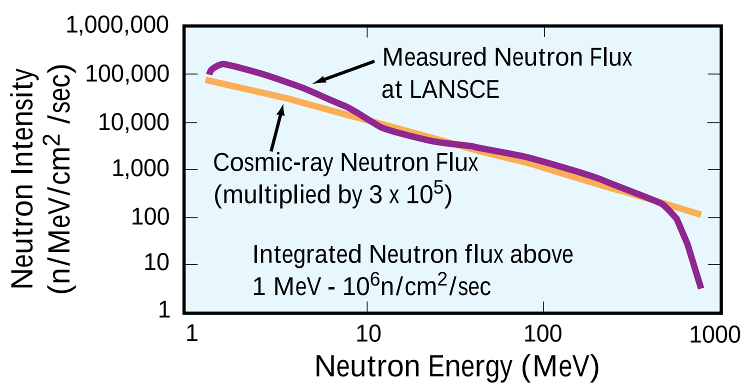


▲ Fig. 2. Photo of the NPB experimental setup. In the center is the liquid hydrogen target with a thin exit window. To the left is a bank of six proton detectors, and on the right are the neutron detectors.

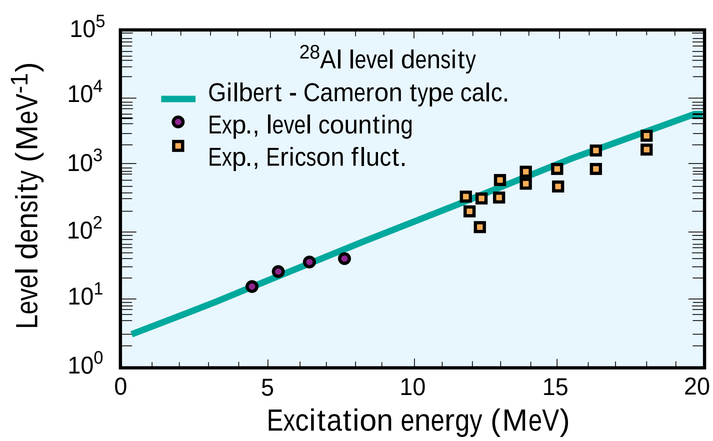
Neutron radiography on 4FP30L. At the second detector location on 4FP30L at 40 meters from the neutron-production target, Dr. Terry Taddeucci is developing techniques for neutron radiography for SBSS applications.

Neutron dosimetry on 4FP30L. Another experiment on 4FP30L was performed by Dr. Nolan Hertel and researchers from Georgia Tech. This group is studying the energy deposited in biological equivalent materials by high-energy neutrons. The results of these measurements will be the Ph.D. thesis of Michele Sutton from Georgia Tech.

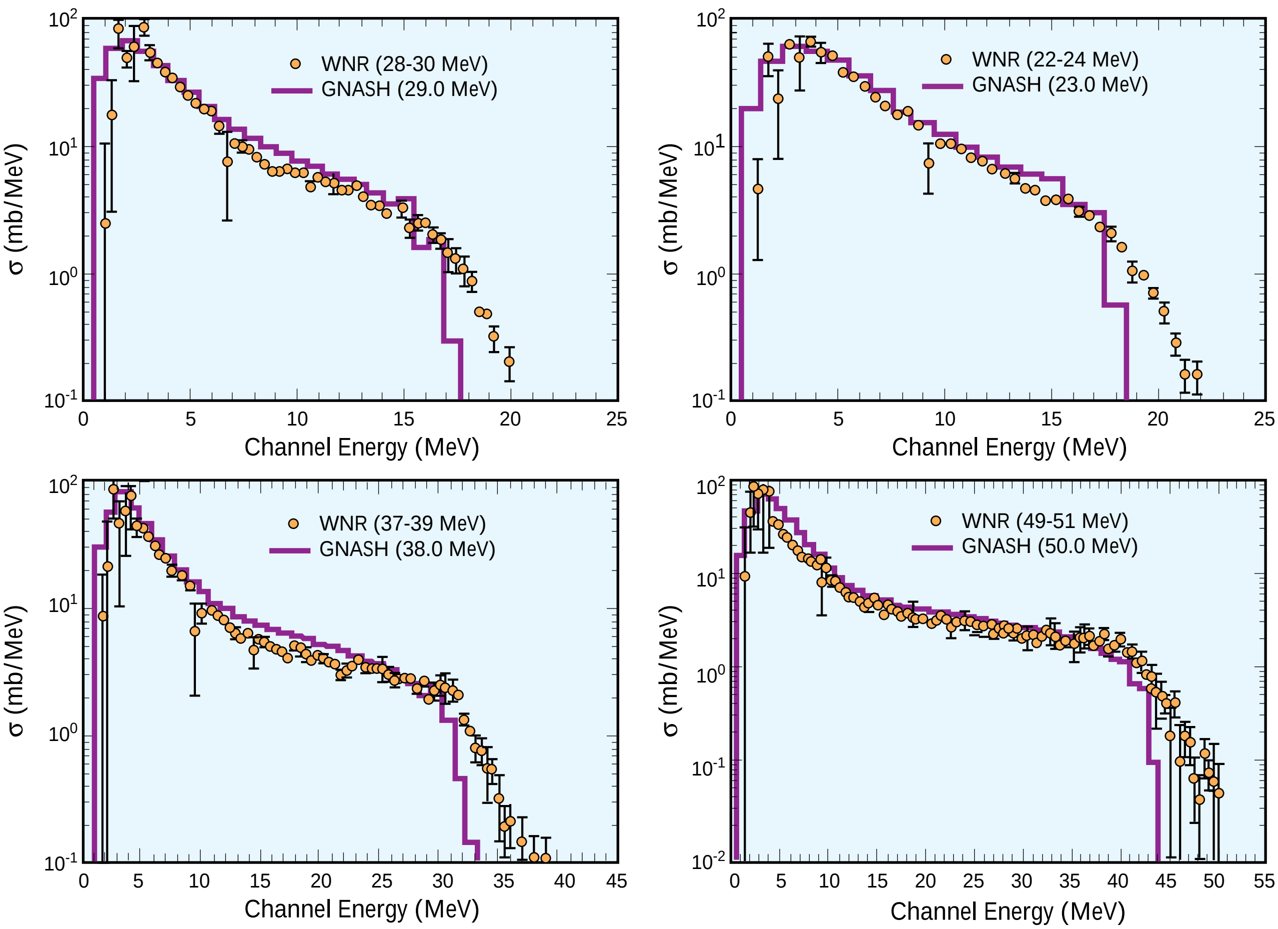
Level density studies on 4FP90L. Dr. Robert Haight and collaborators from Ohio University are measuring neutron-induced charged particle reactions as a way of determining nuclear level densities (Fig. 4). Level densities are essential input to nuclear-reaction model codes, which are used to calculate cross sections and emission spectra. Reactions on silicon were previously studied to improve the calculational models for understanding radiation damage effects on semiconductors. Experiments this year have focused on the mass 90 region.



▲ Fig. 3. A plot of the neutron spectrum produced by cosmic rays hitting the atmosphere and the neutron spectrum produced at WNR on 4FP30L. The atmospheric cosmic-ray flux is multiplied by approximately 300,000.



▲ Fig. 4(a). The nuclear level density for ^{28}Al is plotted versus excitation energy, both measured values and a smooth interpolation.



▲ Fig. 4(b). The information in Fig. 4(a) is used with the level densities (many unknown) of residual nuclei in competing channels to calculate the proton emission spectra shown in Fig. 4(b) for silicon bombarded with neutrons of various energies, resulting in reactions such as $^{28}Si(n,p)^{28}Al$, $^{28}Si(n,np)^{27}Al$, and so forth.

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